7.8.6 Process Calculations

Engineering Design File

PROJECT FILE NO. 021052

Process Calculations for the OU 7-10 Glovebox Excavator Method Project

Prepared for:
U.S. Department of Energy
Idaho Operations Office
Idaho Falls, Idaho

INEEL
Idaho National Engineering
and Environmental Laboratory

Form 412.14
07/24/2001
Rev. 03

ENGINEERING DESIGN FILE

1. Title: OU 7-10 Glovebox Excavator Method Process Calculations

2. Project File No.: 021052

3. Index Codes:
   Building/Type WMF-671   SSC ID N/A   Site Area 098

4. Summary:

This Engineering Design File (EDF) contains the process calculations (e.g., volumes and processing rates) for the Operable Unit (OU) 7-10 (Pit 9) Glovebox Excavator Method Project at the Subsurface Disposal Area within the Radioactive Waste Management Complex of the Idaho National Engineering and Environmental Laboratory. The calculations were performed using Mathcad 2001i.

This revision (Revision 2) of the EDF corrects an error in the throughput rate calculations and rearranges the document to place the earlier conceptual design calculations (previously Section A) in Appendix B, for historical record and comparison.

Some of these calculations were duplicated within and in support of the detailed process model, which is documented in EDF-2158, *OU 7-10 Glovebox Excavator Method Process Model.* While those calculations provided a snapshot verification of the title design calculations reported in this EDF, at time of publication, the calculations could change to support scenario variation studies. Such changes do not supercede the official calculations reported in this EDF.

Rate calculations in this EDF are based on times predicted by the process model. These times have been reduced significantly since conceptual design, because of enhanced process knowledge, resulting in greatly increased throughput rates. However, the numbers are very optimistic, best-case estimates based on an assumption that no off-normal events or unexpected discoveries will occur. Assay is not included in these rates.

5. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
   (See instructions for definitions of terms and significance of signatures.)

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7. Does document contain sensitive unclassified information? ☐ Yes ☒ No
   If Yes, what category:

8. Can document be externally distributed? ☒ Yes ☐ No

9. Uniform File Code: 6400   Disposition Authority: ENV1-k-2-b
   Record Retention Period: Cutoff at project completion. Destroy 25 years after project completion.

10. For QA Records Classification Only: ☐ Lifetime ☒ Nonpermanent ☐ Permanent
    Item and activity to which the QA Record apply:

11. NRC related? ☐ Yes ☒ No

12. Registered Professional Engineer's Stamp (if required)

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OU 7-10 GLOVEBOX EXCAVATOR METHOD PROCESS CALCULATIONS
Engineering Design File (EDF) 3125, Revision 2

Title Design Calculations - This Engineering Design File (EDF) contains the process calculations (quantities, volumes, and processing rates) for the Operable Unit (OU) 7-10 Glovebox Excavator Method Project at the Subsurface Disposal Area within the Radioactive Waste Management Complex of the Idaho National Engineering and Environmental Laboratory (INEEL). Improved knowledge of pit conditions and detailed process definition led to revised assumptions, from the conceptual design process calculations (Revision 0), resulting in a revision of the calculations for title design (Revision 1). This revision (Revision 2) removes throughput rate calculations for all but the nominal angle of repose (52 degrees), and it rearranges the document to move the earlier conceptual design calculations (Section A in Revision 1) to a newly created Appendix B. Changes from Revision 1 to Revision 2 are shaded. Appendix A provides calculations to support the process flow diagrams (PFDs). Detailed process modeling has been performed using these calculations. Some of these calculations were performed again within and in support of the process model and are reported in EDF-2158, *OU 7-10 Glovebox Excavator Method Process Model.* While those calculations provided a snapshot verification of the title design calculations reported in this EDF, at time of publication, they could change to support scenario variation studies. Such changes, in the model, do not supercede the official calculations reported in this EDF.

DESCRIPTION:

These calculations show the volumes, weights and processing rates expected during the retrieval operations under the OU 7-10 Glovebox Excavator Method Project.

GENERAL ASSUMPTIONS:

1. Depth of overburden is 3.5 ft.
   [Source: Process engineering assumption, Mark Borland, based on probe data in *OU 7-10 Stage 1 Subsurface Exploration and Treatability Studies Report (Draft)*, INEEL/EXT-2000-00403, 2000]
   $D_{OB} := 3.5 \cdot ft$

2. Depth of waste is 7.5 ft.
   [Source: Same as assumption #1.]
   $D_W := 7.5 \cdot ft$

3. Excavation Area is a fan shape with 145-degree angle and 20-ft radius.
   [Source: Civil Engineering Decision--Scott Jensen, 10/01]
   $\theta := 145 \cdot deg$
   $r_o := 20 \cdot ft$

4. Typical angle of repose during excavation of INEEL soil is 52 degrees.
   [Source: INEEL Materials Testing Laboratory, Craig Bean, 11/01]
   $\beta_1 := 52 \cdot deg$

5. Range of angle of repose to consider is 45 to 60 degrees.
   [Source: Process Engineering Decision, Mark Borland, 10/01]
   $\beta_2 := 45 \cdot deg$
   $\beta_3 := 60 \cdot deg$

6. Average density of unexcavated soil at RWMC is 100 lb/ft^3.
   [Source: INEEL Materials Testing Laboratory, Craig Bean, 11/01]
   $\rho := 100 \cdot \frac{lb}{ft^3}$

7. Average density of excavated INEEL soil is 75 lb/ft^3.
   [Source: INEEL Materials Testing Laboratory, Craig Bean, 11/01]
   $\rho_{exc} := 75 \cdot \frac{lb}{ft^3}$

8. Drum shells have decayed or disintegrated, leaving only a fragmentary remnant. Void spaces within drums have been filled with interstitial soil that has subsided. Subsidence depressions on the surface have been refilled and leveled. The volume of waste within a decayed drum is 6 ft^3.
   $V_{dw} := 6 \cdot ft^3$

9. Number of shifts per day is 2
   $shift\_rate := 2 \cdot \frac{shifts}{day}$

I. OVERBURDEN CALCULATIONS

Assumptions:

1. Overburden will be packaged in sacks in 4 x 4 x 4-ft stands.
[Source: Process Engineering Decision--Mark Borland 11/01]

2. Amount of soil in 4 x 4 x 4-ft sacks is limited to 5000 lb each to protect the box from overloading.
[Source: Process Engineering Assumption--Stephanie Walsh, 11/01]

3. Sacks will be filled to an average of 8 in. from the top.
[Source: Process Engineering Decision--Stephanie Walsh 11/01]

4. Overburden is shored to 3.5 ft deep.
[Source: Civil Engineering Decision--Scott Jensen, 10/01]

5. Overburden retrieval is estimated to take 8 days if no off-normal events occur. [Source: Process Model, Danny Anderson, 5/02 (EDF-2158)] $T_{ob} := 8 \cdot days$

A. Volume of Overburden

$$A_{OB} := \left(\frac{\theta}{360 \cdot deg}\right) \cdot \pi \cdot r_o^2$$

$A_{OB} = 506\,ft^2$ Overburden excavation area

$$V_{OB} := A_{OB} \cdot D_{OB}$$

$V_{OB} = 1772\,ft^3$

$V_{OB} = 66\,yd^3$ Undisturbed overburden soil volume

$$f_{se} := \text{round}\left(\frac{\rho}{\rho_{exc}}, 2\right)$$

$f_{se} = 1.33$ Soil expansion factor (to nearest 1/100)

$$V_{OB\_exc} := V_{OB} \cdot f_{se}$$

$V_{OB\_exc} = 2356\,ft^3$

$V_{OB\_exc} = 87\,yd^3$ Excavated overburden soil volume

B. Number of Overburden Sacks and Weight of Each Sack

$V_{sack} := (4 \cdot ft) \cdot (4 \cdot ft) \cdot (3 \cdot ft + 4 \cdot in)$ — Volume of a 4 x 4 x 4-ft sack, filled to 8 in. from top

$V_{sack} = 53.3\,ft^3$

$V_{OB\_Scoop} := 5 \cdot ft^3$ — Volume of an excavator scoop of overburden

$$ScoopsPerSack := floor\left(\frac{V_{sack}}{V_{OB\_Scoop}}\right)$$ Number of scoops to fill a sack

$$n_{OB\_Scoops} := \frac{V_{OB\_exc}}{V_{OB\_Scoop}}$$ Total number of overburden excavator scoops

$$Sacks := ceil\left(\frac{n_{OB\_Scoops}}{ScoopsPerSack}\right)$$

$Sacks = 48\,sacks$ — Number of 4 x 4 x 4-ft sacks

$W_{sack} := V_{sack} \cdot \rho_{exc}$

$W_{sack} = 4000\,lb$ — Total weight of a sack < 5000 lb

Sack weight is acceptable.

C. Estimated Overburden Retrieval Rate

$$Rate\_OB\_sacks := \frac{Sacks}{(T_{ob}) \cdot \left(2 \cdot \frac{shifts}{day}\right)}$$

$$Rate\_OB\_sacks = 3\,\frac{sack}{shift}$$ Estimated retrieval rate for sacks of overburden

$Rate\_OB := Rate\_OB\_sacks \cdot V_{sack}$

$$Rate\_OB = 160\,\frac{ft^3}{shift}$$ Estimated retrieval rate for sacks of overburden

II. WASTE CALCULATIONS - UNDISTURBED RETRIEVAL ZONE

Assumptions:

1. The pit inventory for the 40 x 40-ft area of investigation is an accurate estimate of the types of materials to be excavated in this project. The amounts are assumed to scale proportionally with the volume to be excavated. The materials estimated to be located in the 40 x 40-ft area down to underburden include the following:

741 Sludge	$N_{741} := 3 \cdot \text{drums}$
742 Sludge	$N_{742} := 27 \cdot \text{drums}$
743 Sludge	$N_{743} := 379 \cdot \text{drums}$
744 Sludge	$N_{744} := 2 \cdot \text{drums}$
745 Sludge	$N_{745} := 42 \cdot \text{drums}$
Graphite	$N_g := 22 \cdot \text{drums}$
Combustible Debris	$N_{cd} := 260 \cdot \text{drums}$
Noncombustible Debris	$N_{nd} := 28 \cdot \text{drums}$
Empty Drums	$N_e := 544 \cdot \text{drums}$

[Source: Einerson and Thomas, 1999, *Pit 9 Estimated Inventory of Radiological and Nonradiological Constituents*, INEEL/EXT-99-00602]

2. The buried drums are randomly and uniformly distributed so that the number of each type of drum within the actual retrieval pit can be scaled from the inventory in Assumption 1 by the ratio of the volumes of the waste layers. [Source: Process Engineering Assumption, Danny Anderson, 11/01]

3. Packing factors for metals:
[Source: Process Engineering Assumption, Mark Borland, 11/01]

For noncombustible debris = 100% (not compactible) $PF_{nd} := 1.0$ i.e., assume one 55-gal drum-worth of metal debris fills one 85-gal overpack

4. Waste Expansion Factor

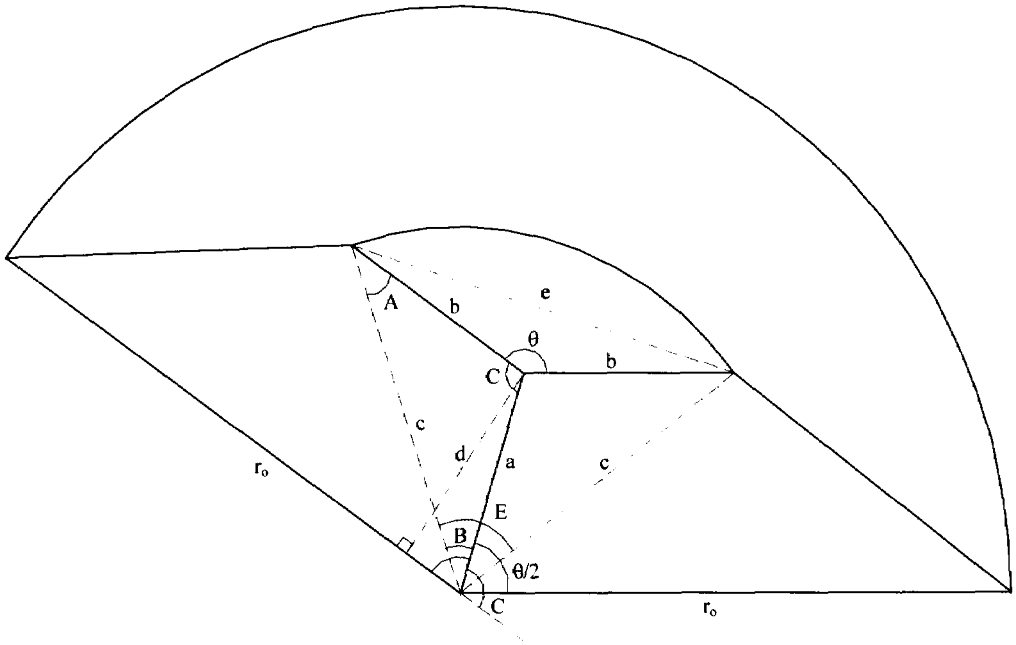
for compressable wastes (i.e., sludges, combustible debris, and graphite) = 20% $f_{we} := 1.2$ i.e., assume that these wastes expand by 20% when they are retrieved (like soil but to a lesser degree)

5. Each original drum is assumed to have decayed, but a remnant remains. It is assumed that six remnants can be packaged into an 85-gal drum.
[Source: Process Engineering Assumption, Danny Anderson, 5/02]

$ndf := 6$ Number of drum fragments that can be packaged into an 85-gal drum

A. Pit Volume in Waste Zone (Undisturbed)

Pit Shape



Dimension Definitions (as functions of angle of repose and pit depth)

$$a(\beta, D) := \frac{D}{\tan(\beta)\cdot\sin\left(\frac{\theta}{2}\right)} \qquad c(\beta, D) := r_o - \frac{D}{\tan(\beta)} \qquad E(\beta, D) := \theta - 2\cdot\operatorname{asin}\left(\frac{a(\beta, D)}{c(\beta, D)}\cdot\sin\left(\frac{\theta}{2}\right)\right)$$

Area of Fan Shape (at any depth and angle of repose)

$$A(\beta, D) := \frac{c(\beta, D)^2}{2}\cdot\left[(\sin(\theta))\cdot\left(\frac{1-\cos(E(\beta, D))}{1-\cos(\theta)}\right) + (E(\beta, D) - \sin(E(\beta, D)))\right]$$

Total Volume of Waste Zone (undisturbed)

$$V(\beta) := \int_0^{D_w} A(\beta, D)\, dD$$

$V(\beta_1) = 78.5\,\text{yd}^3$	$V(\beta_1) = 2121\,\text{ft}^3$	Volume of waste zone (52-degree angle of repose)
$V(\beta_2) = 65.6\,\text{yd}^3$	$V(\beta_2) = 1771\,\text{ft}^3$	Volume of waste zone (45-degree angle of repose)
$V(\beta_3) = 92.4\,\text{yd}^3$	$V(\beta_3) = 2496\,\text{ft}^3$	Volume of waste zone (60-degree angle of repose)

B. Drum Inventory in Retrieval Zone

Pit Size Scale Factor:
To estimate the amounts of different types of materials in the pit area to be excavated (the retrieval zone), a scale factor must be applied to the 40 x 40-ft investigation area. This scale factor is a ratio of the volumes, and as such, will vary with the angle of repose during excavation.

$$V_{40x40} := (40 \cdot \text{ft}) \cdot (40 \cdot \text{ft}) \cdot D_w$$

$V_{40x40} = 444.4\,\text{yd}^3$ Volume of waste in 40 x 40-ft investigation pit.

$V_{40x40} = 12000\,\text{ft}^3$

$$sf(\beta) := \frac{V(\beta)}{V_{40x40}}$$

$sf(\beta_1) = 0.177$	Scale factor (52-degree angle of repose)
$sf(\beta_2) = 0.148$	Scale factor (45-degree angle of repose)
$sf(\beta_3) = 0.208$	Scale factor (60-degree angle of repose)

Scaled Waste Drum Inventory (anticipated drums in selected retrieval zone)

741 Sludge	$N_{741}(\beta) := \text{roundup}(N_{741} \cdot sf(\beta))$	$N_{741}(\beta_1) = 1$ drum $N_{741}(\beta_2) = 1$ drum $N_{741}(\beta_3) = 1$ drum
742 Sludge	$N_{742}(\beta) := \text{roundup}(N_{742} \cdot sf(\beta))$	$N_{742}(\beta_1) = 5$ drums $N_{742}(\beta_2) = 4$ drums $N_{742}(\beta_3) = 6$ drums
743 Sludge	$N_{743}(\beta) := \text{roundup}(N_{743} \cdot sf(\beta))$	$N_{743}(\beta_1) = 67$ drums $N_{743}(\beta_2) = 56$ drums $N_{743}(\beta_3) = 79$ drums
744 Sludge	$N_{744}(\beta) := \text{roundup}(N_{744} \cdot sf(\beta))$	$N_{744}(\beta_1) = 1$ drum $N_{744}(\beta_2) = 1$ drum $N_{744}(\beta_3) = 1$ drum
745 Sludge	$N_{745}(\beta) := \text{roundup}(N_{745} \cdot sf(\beta))$	$N_{745}(\beta_1) = 8$ drums $N_{745}(\beta_2) = 7$ drums $N_{745}(\beta_3) = 9$ drums
Graphite	$N_g(\beta) := \text{roundup}(N_g \cdot sf(\beta))$	$N_g(\beta_1) = 4$ drums $N_g(\beta_2) = 4$ drums $N_g(\beta_3) = 5$ drums
Comb. Debris	$N_{cd}(\beta) := \text{roundup}(N_{cd} \cdot sf(\beta))$	$N_{cd}(\beta_1) = 46$ drums $N_{cd}(\beta_2) = 39$ drums $N_{cd}(\beta_3) = 55$ drums
Noncomb. Debris	$N_{nd}(\beta) := \text{roundup}(N_{nd} \cdot sf(\beta))$	$N_{nd}(\beta_1) = 5$ drums $N_{nd}(\beta_2) = 5$ drums $N_{nd}(\beta_3) = 6$ drums
Empty Drums	$N_e(\beta) := \text{roundup}(N_e \cdot sf(\beta))$	$N_e(\beta_1) = 97$ drums $N_e(\beta_2) = 81$ drums $N_e(\beta_3) = 114$ drums

C. Waste and Interstitial Soil Volumes (undisturbed)

Total Number of Sludge Drums in Retrieval Zone

$$N_s(\beta) := N_{741}(\beta) + N_{742}(\beta) + N_{743}(\beta) + N_{744}(\beta) + N_{745}(\beta)$$

Total Number of Waste Drums in Retrieval Zone

$$N_T(\beta) := N_s(\beta) + N_g(\beta) + N_{cd}(\beta) + N_{nd}(\beta) + N_e(\beta)$$

$N_T(\beta_1) = 234\,\text{drums}$ Waste drums in retrieval zone (52-degree repose)

$N_T(\beta_2) = 198\,\text{drums}$ Waste drums in retrieval zone (45-degree repose)

$N_T(\beta_3) = 276\,\text{drums}$ Waste drums in retrieval zone (60-degree repose)

Volume of Undisturbed Waste in Retrieval Zone (not including decayed drum fragments)

$$V_w(\beta) := \left[\left(N_s(\beta) + N_g(\beta) + N_{cd}(\beta)\right) + N_{nd}(\beta)\right] \cdot V_{dw}$$

$V_w(\beta_1) = 30.4\,\text{yd}^3$ Volume of drum waste (52-degree repose)

$V_w(\beta_2) = 26\,\text{yd}^3$ Volume of drum waste (45-degree repose)

$V_w(\beta_3) = 36\,\text{yd}^3$ Volume of drum waste (60-degree repose)

Volume of Undisturbed Interstitial Soil in Retrieval Zone

$$V_i(\beta) := V(\beta) - V_w(\beta)$$

$V_i(\beta_1) = 48.1\,\text{yd}^3$ Volume of interstitial soil (52-degree repose)

$V_i(\beta_2) = 39.6\,\text{yd}^3$ Volume of interstitial soil (45-degree repose)

$V_i(\beta_3) = 56.4\,\text{yd}^3$ Volume of interstitial soil (60-degree repose)

D. Waste and Interstitial Soil Volumes (retrieved/expanded)

Expanded Volume of Retrieved Waste in Retrieval Zone (not including decayed drum fragments)

$$V_{wr}(\beta) := \left[\left(N_s(\beta) + N_g(\beta) \bullet N_{cd}(\beta)\right)\cdot f_{we} + N_{nd}(\beta)\right]\cdot V_{dw}$$

$V_{wr}(\beta_1) = 36.3\,yd^3$ Volume of drum waste (52-degree repose)

$V_{wr}(\beta_2) = 31\,yd^3$ Volume of drum waste (45-degree repose)

$V_{wr}(\beta_3) = 42.9\,yd^3$ Volume of drum waste (60-degree repose)

Expanded Volume of Retrieved Interstitial Soil in Retrieval Zone

$$V_{ir}(\beta) := \left(V(\beta) - V_w(\beta)\right)\cdot f_{se}$$

$V_{ir}(\beta_1) = 64\,yd^3$ Volume of interstitial soil (52-degree repose)

$V_{ir}(\beta_2) = 52.6\,yd^3$ Volume of interstitial soil (45-degree repose)

$V_{ir}(\beta_3) = 75.1\,yd^3$ Volume of interstitial soil (60-degree repose)

III. WASTE CALCULATIONS - REPACKAGED MATERIALS

Assumptions:

1. 25% of combustible debris drums contain an outlier object that will be bagged out of the glovebox rather than packaged in a 55-gal drum. [Source: Process Engineering Assumption, Mark Borland, 11/01]

$k_{outlier} := 0.25$

2. Noncombustible debris (metals) and decayed drum remnants are all packed in 85-gal overpack drums. [Source: Process Engineering Decision Mark Borland, 5/02]

3. The increase in volume of interstitial soil in the waste zone from excavation is approximately 33% (same as overburden). [Source: Process Engineering Assumption, Mark Borland, 5/02]

4. Upon retrieval, waste expands like soil, but to a lesser degree. Expansion is 20%. (f_{we} = 1.2)
[Source: Process Engineering Assumption, Mark Borland, 5/02]

Volume of soil or waste packaged per 55-gal drum

$$n_{W\_Scoops} := 2 \cdot \frac{\text{scoops}}{\text{drum}}$$

$$V_{W\_Scoop} := 2.5 \cdot \frac{\text{ft}^3}{\text{scoop}}$$

$$V_d := n_{W\_Scoops} \cdot V_{W\_Scoop}$$

Two excavator scoops, of 2.5 ft^3 each, can fit into each 55-gal drum. This is less than would be expected because the soil and waste are packaged into tarp-like cart liners which take up space in the drum.

$$V_d = 5 \frac{\text{ft}^3}{\text{drum}}$$

Expanded soil or waste volume per 55-gal drum

Bagged-Out Outlier Objects

Number of outlier objects to be bagged out (see Assumption II.3)

$$N_{outlier}(\beta) := \text{roundup}\left(N_{cd}(\beta) \cdot k_{outlier}\right)$$

$N_{outlier}(\beta_1) = 12\,\text{outliers}$ Number of outlier objects (52-degree repose)

$N_{outlier}(\beta_2) = 10\,\text{outliers}$ Number of outlier objects (45-degree repose)

$N_{outlier}(\beta_3) = 14\,\text{outliers}$ Number of outlier objects (60-degree repose)

A. Total Number of 55-gal Drums of Repackaged Waste Material

55-gal Drums - Repackaged Drum Waste

$$N_{sludge}(\beta) := \mathrm{roundup}\left(\frac{\mathrm{rounddown}\left(N_s(\beta)\cdot V_{dw}\cdot\frac{f_{we}}{V_{W\_Scoop}}\right)}{n_{W\_Scoops}}\right)$$

$N_{sludge}(\beta_1) = 118$ drums — Number of sludge drums (52-degree repose)
$N_{sludge}(\beta_2) = 99$ drums — Number of sludge drums (45-degree repose)
$N_{sludge}(\beta_3) = 138$ drums — Number of sludge drums (60-degree repose)

$$N_{cdebris}(\beta) := \mathrm{roundup}\left(\frac{\mathrm{rounddown}\left(N_{cd}(\beta)\cdot V_{dw}\cdot\frac{f_{we}}{V_{W\_Scoop}}\right)}{n_{W\_Scoops}}\right)$$

$N_{cdebris}(\beta_1) = 66$ drums — Number of comb. debris drums (52-degree repose)
$N_{cdebris}(\beta_2) = 56$ drums — Number of comb. debris drums (45-degree repose)
$N_{cdebris}(\beta_3) = 79$ drums — Number of comb. debris drums (60-degree repose)

$$N_{graphite}(\beta) := \mathrm{roundup}\left(\frac{\mathrm{rounddown}\left(N_g(\beta)\cdot V_{dw}\cdot\frac{f_{we}}{V_{W\_Scoop}}\right)}{n_{W\_Scoops}}\right)$$

$N_{graphite}(\beta_1) = 6$ drums — Number of graphite drums (52-degree repose)
$N_{graphite}(\beta_2) = 6$ drums — Number of graphite drums (45-degree repose)
$N_{graphite}(\beta_3) = 7$ drums — Number of graphite drums (60-degree repose)

55-gallon Drums - Repackaged Interstitial Soil

$$N_{intsoil}(\beta) := \mathrm{roundup}\left(\frac{V_{ir}(\beta)}{V_{W\_Scoop}\cdot n_{W\_Scoops}}\right)$$

$N_{intsoil}(\beta_1) = 346$ drums — Repackaged interstitial soil drums (52-degree repose)
$N_{intsoil}(\beta_2) = 285$ drums — Repackaged interstitial soil drums (45-degree repose)
$N_{intsoil}(\beta_3) = 406$ drums — Repackaged interstitial soil drums (60-degree repose)

Total Number of 55-gallon Drums of Repackaged Waste

Total Number of Packaged 55-gal Drums $N_{55}(\beta) := N_{sludge}(\beta) + N_{graphite}(\beta) + N_{cdebris}(\beta) + N_{intsoil}(\beta)$

$N_{55}(\beta_1) = 536$ drums	55-gal drums of repackaged waste (52-degree repose)
$N_{55}(\beta_2) = 446$ drums	55-gal drums of repackaged waste (45-degree repose)
$N_{55}(\beta_3) = 630$ drums	55-gal drums of repackaged waste (60-degree repose)

B. 85-gallon Overpack Drums

Number of 85-gal Overpacks Filled with Noncombustible Debris (Metal) $N_{85.nd}(\beta) := N_{nd}(\beta)$

Number of 85-gal Overpacks Filled with Decayed Drum Remnants $N_{85.dr}(\beta) := \text{roundup}\left(\frac{N_T(\beta)}{ndf}\right)$

Total 85-gal Overpacks $N_{85}(\beta) := N_{85.nd}(\beta) + N_{85.dr}(\beta)$

$N_{85}(\beta_1) = 44$ drums	85-gal overpack drums of repackaged waste (52-degree repose)
$N_{85}(\beta_2) = 38$ drums	85-gal overpack drums of repackaged waste (45-degree repose)
$N_{85}(\beta_3) = 52$ drums	85-gal overpack drums of repackaged waste (60-degree repose)

C. Total Number of Drums of Repackaged Waste

$N_{tot}(\beta) := N_{55}(\beta) + N_{85}(\beta)$

$N_{tot}(\beta_1) = 580$ drums	Drums of repackaged waste (52-degree angle of repose)
$N_{tot}(\beta_2) = 484$ drums	Drums of repackaged waste (45-degree angle of repose)
$N_{tot}(\beta_3) = 682$ drums	Drums of repackaged waste (60-degree angle of repose)

D. Number of Waste Batches

Assumptions:

1. Batch size is an average 2.5 ft^3. A batch is the amount of material per scoop of the excavator.
   [Source: Process Engineering Decision based on amount readily handled in glovebox tray, Mark Borland, 10/01]

$$Batch(\beta) := \frac{V_{wr}(\beta) + V_{ir}(\beta)}{V_{W\_Scoop}}$$

$Batch(\beta_1) = 1083$ batches	Number of batches (52-degree angle of repose)
$Batch(\beta_2) = 903$ batches	Number of batches (45-degree angle of repose)
$Batch(\beta_3) = 1274$ batches	Number of batches (60-degree angle of repose)

IV. PACKAGING RATE CALCULATIONS

A. Drum Output Rate

Assumptions:

1. Waste retrieval is estimated to take 19.1 days if no off-normal events occur. These throughput rates do not include assay. Throughput rates are calculated only for the nominal angle of repose of 52 degrees. At other angles, the volume will change, but the retrieval time should also change proportionately, and the rate should remain fairly constant.
(Source: Process Model, Danny Anderson, 5/02 [EDF-2158])

$$T_{waste} := 19.1 \cdot \text{days}$$

$$\text{Rate\_55}(\beta) := \frac{N_{55}(\beta)}{(T_{waste}) \cdot 2 \cdot \frac{\text{shifts}}{\text{day}}}$$

$$\text{Rate\_55}(\beta_1) = 14 \frac{\text{drums}}{\text{shift}}$$

Output rate for repackaged 55-gal drums (52-degree angle)

$$\text{Rate\_85}(\beta) := \frac{N_{85}(\beta)}{(T_{waste}) \cdot 2 \cdot \frac{\text{shifts}}{\text{day}}}$$

$$\text{Rate\_85}(\beta_1) = 1.2 \frac{\text{drums}}{\text{shift}}$$

Output rate for repackaged 85-gal drums (52-degree angle)

$$\text{Rate\_waste}(\beta) := \frac{N_{tot}(\beta)}{(T_{waste}) \cdot 2 \cdot \frac{\text{shifts}}{\text{day}}}$$

$$\text{Rate\_waste}(\beta_1) = 15.2 \frac{\text{drums}}{\text{shift}}$$

Output rate for repackaged waste (52-degree angle)

B. Volume Output Rate

$$\text{Rate\_vol}(\beta) := \frac{V(\beta)}{(T_{waste}) \cdot 2 \cdot \frac{\text{shifts}}{\text{day}}}$$

$$\text{Rate\_vol}(\beta_1) = 55.5 \frac{\text{ft}^3}{\text{shift}}$$

Output rate for repackaged waste (52-degree angle)

TITLE DESIGN CALCULATION SUMMARY

I. Overburden

$V_{OB} = 66\,yd^3$	Undisturbed overburden soil volume
$V_{OB\_exc} = 87\,yd^3$	Excavated Overburden Soil Volume
$Sacks = 48\,sacks$	Number of 4 x 4 x 4-ft sacks
$W_{sack} = 4000\,lb$	Total weight of a sack < 5000 lb
$Rate\_OB\_sacks = 3\,\frac{sack}{shift}$	Required retrieval rate for sacks of overburden

II. Waste -- Undisturbed Retrieval Zone

$V(\beta_1) = 78.5\,yd^3$	$V(\beta_1) = 2121\,ft^3$	Volume of waste zone (52-degree angle of repose)
$V(\beta_2) = 65.6\,yd^3$	$V(\beta_2) = 1771\,ft^3$	Volume of waste zone (45-degree angle of repose)
$V(\beta_3) = 92.4\,yd^3$	$V(\beta_3) = 2496\,ft^3$	Volume of waste zone (60-degree angle of repose)

III. Waste - Repackaged Materials

$N_{55}(\beta_1) = 536\,drums$	55-gal drums of repackaged waste (52-degree repose)
$N_{55}(\beta_2) = 446\,drums$	55-gal drums of repackaged waste (45-degree repose)
$N_{55}(\beta_3) = 630\,drums$	55-gal drums of repackaged waste (60-degree repose)
$N_{85}(\beta_1) = 44\,drums$	85-gal overpack drums of repackaged waste (52-degree repose)
$N_{85}(\beta_2) = 38\,drums$	85-gal overpack drums of repackaged waste (45-degree repose)
$N_{85}(\beta_3) = 52\,drums$	85-gal overpack drums of repackaged waste (60-degree repose)
$N_{tot}(\beta_1) = 580\,drums$	Drums of repackaged waste (52-degree angle of repose)
$N_{tot}(\beta_2) = 484\,drums$	Drums of repackaged waste (45-degree angle of repose)
$N_{tot}(\beta_3) = 682\,drums$	Drums of repackaged waste (60-degree angle of repose)
$Batch(\beta_1) = 1083\,batches$	Number of batches (52-degree angle of repose)
$Batch(\beta_2) = 903\,batches$	Number of batches (45-degree angle of repose)
$Batch(\beta_3) = 1274\,batches$	Number of batches (60-degree angle of repose)

$$\text{Rate\_55}(\beta_1) = 14\,\frac{\text{drums}}{\text{shift}}$$ Output rate for repackaged 55-gal drums (52-degree angle)

$$\text{Rate\_85}(\beta_1) = 1.2\,\frac{\text{drums}}{\text{shift}}$$ Output rate for repackaged 85-gal drums (52-degree angle)

$$\text{Rate\_waste}(\beta_1) = 15.2\,\frac{\text{drums}}{\text{shift}}$$ Output rate for repackaged waste (52-degree angle)

$$\text{Rate\_vol}(\beta_1) = 55.5\,\frac{\text{ft}^3}{\text{shift}}$$ Output rate for repackaged waste (52-degree angle)

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Appendix A
Process Flow Diagram Calculations

This appendix supports and cross-references calculated quantities and rates that are reported in the Title Design Process Flow Diagrams (Drawing 522048, Sheets 1, 2, and 3). Some the values were calculated and reported previously in the main body of this EDF, but are repeated here. Others are new calculations that are only documented in this appendix. Boxed numbers refer to stream numbers on the Process Flow Diagrams. This entire appendix is new; it was not part of Revision 0 of this EDF.

I. PRIMARY WASTE STREAMS (100 SERIES) — Assumed angle of repose: $\beta := 52 \cdot \text{deg}$

A. Overburden [Sheets 1 & 2]

$\boxed{151}$	Overburden Soil	Overburden volume	$V_{OB} = 66\,\text{yd}^3$
		Number of soil sacks	$\text{Sacks} = 48\,\text{sacks}$
		Maximum volume of soil in a sack	$V_{sack} = 53.3\,\text{ft}^3$
		Soil sack fill rate	$\text{Rate\_OB\_sacks} = 3\,\dfrac{\text{sacks}}{\text{shift}}$
		Overburden volumetric retrieval rate	$\text{Rate\_OB} = 160\,\dfrac{\text{ft}^3}{\text{shift}}$

B. 55 and 85-gal Drums, Processed Waste [Sheets 1 & 3]

$\boxed{101}$	Total Drum processing rate	$\text{Rate\_waste}(\beta) = 15.2\,\dfrac{\text{drums}}{\text{shift}}$
	Number of 55-gal drums	$N_{55}(\beta) = 536\,\text{drums}$
	55-gal drum processing rate	$\text{Rate\_55}(\beta) = 14\,\dfrac{\text{drums}}{\text{shift}}$
$\boxed{102}$	Number of 85-gal drums	$N_{85}(\beta) = 44\,\text{drums}$
	85-gal drum processing rate	$\text{Rate\_85}(\beta) = 1.2\,\dfrac{\text{drums}}{\text{shift}}$

C. Total Pit Waste (drum counts refer to post-handling, filled drums)

$\boxed{104}$ Total Pit Waste — Pit Volume (undisturbed) — $V(\beta) = 78.5\,yd^3$

Drum processing rate — $Rate\_waste(\beta) = 15.2\,\frac{drums}{shift}$

Volume processing rate — $Rate\_vol(\beta) = 55.5\,\frac{ft^3}{shift}$

D. Pit Waste Drums Requiring Special Processing (drum counts refer to original drums in pit)

$\boxed{105}$ Empty coolant drums [Sheet 3] — $N_e(\beta) = 97\,drums$

(All drums are assumed to be decayed, with only a remnant remaining.)

$\boxed{106}$ Outlier waste objects [Sheet 3] — $N_{outlier}(\beta) = 12\,outliers$

(Based on the assumption that 25% of the combustible debris drums will each yield one outlier.)

$\boxed{108}$ Miscellaneous noncombustible drums (metals) — $N_{nd}(\beta) = 5\,drums$

II. SAMPLES (200 SERIES)

A. Underburden Samples

(Reference: Conversation with Daryl Haefner. Will be documented in Field Sampling Plan.)

$\boxed{202}$ Underburden samples [Sheets 1 & 2]

Number of underburden samples $n_{us} := 6 \cdot \text{samples}$

B. Pit Waste Samples

$\boxed{201}$ Waste Samples [Sheets 1 & 3]

Number of samples (aliquots) per scoop $n_{aps} := 1 \cdot \frac{\text{aliquot}}{\text{scoop}}$

Number of samples per bottle $n_{apb} := 10 \cdot \frac{\text{aliquots}}{\text{bottle}}$

Number of cartloads to be sampled

$$n_{cl} := \left(N_{sludge}(\beta) + N_{intsoil}(\beta) + N_{graphite}(\beta)\right) \cdot n_{W\_Scoops}$$

$$n_{cl} = 940\,\text{scoops}$$

Number of sample bottles $n_b := \text{roundup}\left(\frac{n_{aps} \cdot n_{cl}}{n_{apb}}\right)$

$$n_b = 94\,\text{bottles}$$

Average sample rate

$$r_{sample} := \frac{n_b}{T_{waste}} \qquad r_{sample} = 4.9\,\frac{\text{bottles}}{\text{day}}$$

or $$r_{sample} := \frac{n_b}{T_{waste}} \cdot \left(\frac{1}{2} \cdot \frac{\text{day}}{\text{shift}}\right) \qquad r_{sample} = 2.5\,\frac{\text{bottles}}{\text{shift}}$$

C. Unaltered Sample Material Returned from Lab

$\boxed{203}$ Returned Samples — The amount of unaltered sample material that may be returned from INTEC Analytical Laboratory cannot be determined at this time.

III. SECONDARY WASTE (300 SERIES)

Sources:
1. *Waste Management Plan for the OU 7-10 Glovebox Excavator Method (Draft), PLN-343, 07/02*
2. Converstations with Daryl Haefner. Will be documented in the Field Sampling Plan

Definitions from Source 2:

- During overburden removal

  $14\ ft^3$ RCT survey waste and PPE (to RWMC LLW Pit)

- During waste retrieval

  $800\ ft^3$ PPEs from ops in PGS (to RWMC LLW Pit)

  $0 - 14\ ft^3$ PPEs from maintenance at RCS/PGS (to RWMC LLW Pit)

  $180\ ft^3$ PPEs from decon wastes from cleaning PGS (to AMWTF)

  $7\ ft^3$ RadCon survey waste from PGS (to AMWTF)

  $7 - 14\ ft^3$ WES maintenance waste (to CFA landfill)

  $7\ ft^3$ WES Radcon surveys (to RWMC LLW Pit)

A. Overburden Secondary Waste

$\boxed{303}$ Secondary Waste from Overburden Removal (to RWMC LLW Pit) [Sheets 1 & 2]

Drum capacity	$c_d := 7 \cdot \frac{ft^3}{drum}$	
Overburden secondary waste volume	$v_{osw} := 14 \cdot ft^3$	
Drums of overburden secondary waste	$n_{oswd} := \frac{v_{osw}}{c_d}$	$n_{oswd} = 2\,drums$

B. Waste Zone Operations Secondary Waste

$\boxed{301}$ PPEs from Operations in WES (to RWMC LLW Pit) [Sheet 1]

Secondary waste volume	$v_{wsw} := 800 \cdot ft^3 + 14 \cdot ft^3$	$v_{wsw} = 30.1\,yd^3$
Drums of waste from WES	$n_{wswd} := \frac{v_{wsw}}{c_d}$	$n_{wswd} = 116\,drums$
Waste retrieval time		$T_{waste} = 19.1\,days$
Volume rate	$r_{wv} := \frac{v_{wsw}}{T_{waste}} \cdot \left(\frac{1}{2} \cdot \frac{day}{shift}\right)$	$r_{wv} = 21.3\,\frac{ft^3}{shift}$
Drum rate	$r_{wd} := \frac{r_{wv}}{c_d}$	$r_{wd} = 3\,\frac{drums}{shift}$

302 Secondary Waste from Inside (to AMWTF) [Sheets 1 & 3]

Secondary waste volume	$v_{psw} := 180 \cdot ft^3 + 7 \cdot ft^3$	$v_{psw} = 6.9\,yd^3$
Drums of waste from WES	$n_{pswd} := \frac{v_{psw}}{c_d}$	$n_{pswd} = 27\,drums$
Waste retrieval time		$T_{waste} = 19.1\,days$
Volume rate	$r_{pv} := \frac{v_{psw}}{T_{waste}} \cdot \left(\frac{1}{2} \cdot \frac{day}{shift}\right)$	$r_{pv} = 4.9 \frac{ft^3}{shift}$
Drum rate	$r_{pd} := \frac{r_{pv}}{c_d}$	$r_{pd} = 0.7 \frac{drums}{shift}$

304 Non-rad PPEs from WES Activities (to CFA Landfill) [Sheet 1]

Secondary waste volume	$v_{nsw} := 14 \cdot ft^3$	$v_{nsw} = 0.5\,yd^3$
Drums of waste from WES	$n_{nswd} := \frac{v_{nsw}}{c_d}$	$n_{nswd} = 2\,drums$
Volume rate	$r_{nv} := \frac{v_{nsw}}{T_{waste}} \cdot \left(\frac{1}{2} \cdot \frac{day}{shift}\right)$	$r_{nv} = 0.4 \frac{ft^3}{shift}$
Drum rate	$r_{nd} := \frac{r_{nv}}{c_d}$	$r_{nd} = 0.05 \frac{drums}{shift}$

305 Secondary Waste from Rad Surveys of Waste (to RWMC LLW Pit) [Sheet 1]

Secondary waste volume	$v_{rsw} := 7 \cdot ft^3$	
Drums of waste from WES	$n_{rswd} := \frac{v_{rsw}}{c_d}$	$n_{rswd} = 1\,drum$
Rates	N/A	

IV. MISCELLANEOUS MATERIALS (400 SERIES)

$\boxed{401}$ Waste Transfer Cart Trips [Sheets 2 & 3]

All gloveboxes — Number of trips = number of batches

$n_t := \text{Batch}(\beta)$ $\qquad n_t = 1083\,\text{trips}$

Rate of transfer $r_t := \dfrac{n_t}{T_{waste}}$ $\qquad r_t = 56.7\,\dfrac{\text{trips}}{\text{day}}$

$r_t := \dfrac{n_t}{T_{waste}} \cdot \left(\dfrac{1}{2} \cdot \dfrac{\text{day}}{\text{shift}}\right)$ $\qquad r_t = 28.4\,\dfrac{\text{trips}}{\text{shift}}$

Per glovebox — Number of trips per glovebox

$n_{tpg} := \text{roundup}\left(\dfrac{n_t}{3}\right)$ $\qquad n_{tpg} = 362\,\text{trips}$ per glovebox

Rate per glovebox $r_{tpg} := \dfrac{n_{tpg}}{T_{waste}}$ $\qquad r_{tpg} = 19\,\dfrac{\text{trips}}{\text{day}}$ per glovebox

$r_{tpg} := \dfrac{n_{tpg}}{T_{waste}} \cdot \left(\dfrac{1}{2} \cdot \dfrac{\text{day}}{\text{shift}}\right)$ $\qquad r_{tpg} = 9.5\,\dfrac{\text{trips}}{\text{shift}}$ per glovebox

$\boxed{402}$ Overburden Soil Sacks [Sheets 1 & 2] (same as overburden soil stream, units) $\boxed{151}$

Units, total (# of soil sacks) $\qquad \text{Sacks} = 48\,\text{sacks}$

Rate (soil sack fill rate) $\qquad \text{Rate\_OB\_sacks} = 3\,\dfrac{\text{sacks}}{\text{shift}}$

$\boxed{403}$ 55-gal Drum Assemblies [Sheets 1 & 3] (same as 55-gal drum stream, units) $\boxed{101}$

Drums, total (number of 55-gal drums) $\qquad N_{55}(\beta) = 536\,\text{drums}$

Rate (55-gal drum processing rate) $\qquad \text{Rate\_55}(\beta) = 14\,\dfrac{\text{drums}}{\text{shift}}$

$\boxed{404}$ 85-gal Drum Assemblies [Sheets 1 & 3] (same as 85-gal drum stream, units) $\boxed{102}$

Drums, total (number of 85-gal drums) $\qquad N_{85}(\beta) = 44\,\text{drums}$

Rate (85-gal drum processing rate) $\qquad \text{Rate\_85}(\beta) = 1.2\,\dfrac{\text{drums}}{\text{shift}}$

$\boxed{405}$ Absorbants, Fire Supression Sand, and Rad Decon/Survey Materials for PGS [Sheets 1 & 3]

AR = As required

$\boxed{406}$ Waste Cart Liners [Sheet 1 & 3]

Number of trips = number of batches

$n_t := \text{Batch}(\beta)$ $\qquad n_t = 1083\,\text{trips}$

Rate of transfer $r_t := \dfrac{n_t}{T_{waste}}$ $\qquad r_t = 56.7\,\dfrac{\text{trips}}{\text{day}}$

$r_t := \dfrac{n_t}{T_{waste}} \cdot \left(\dfrac{1}{2} \cdot \dfrac{\text{day}}{\text{shift}}\right)$ $\qquad r_t = 28.4\,\dfrac{\text{trips}}{\text{shift}}$

$\boxed{407}$ MgO Fire Suppression [Sheets 2 & 3]

(Source: Conversation with Daryl Lopez. Will be documented in design drawings.)

Volume needed = 2 - 3 ft^3 $\qquad V_{sand} := 3 \cdot ft^3$

Volume per drum $\qquad V_{sd} := 7 \cdot \dfrac{ft^3}{\text{drum}}$

Drums needed $n_{sd} := \dfrac{V_{sand}}{V_{sd}}$ $\qquad n_{sd} = 0.429\,\text{drums}$ $\qquad$ or 1/2 drum

$\boxed{408}$ Absorbant [Sheets 2 & 3]

(Source: Conversation with Daryl Lopez. Will be documented in design drawings.)

Volume needed = 2 - 3 ft^3 $\qquad V_{sand} := 3 \cdot ft^3$

Volume per drum $\qquad V_{sd} := 7 \cdot \dfrac{ft^3}{\text{drum}}$

Drums needed $n_{sd} := \dfrac{V_{sand}}{V_{sd}}$ $\qquad n_{sd} = 0.429\,\text{drums}$ $\qquad$ or 1/2 drum

$\boxed{451}$ Empty Sample Bottles [Seets 1 & 3] (same as waste samples stream) $\boxed{201}$

Units, total (number of sample bottles) $\qquad n_b = 94\,\text{bottles}$

Rate (sample rate) $\qquad r_{sample} = 2.5\,\dfrac{\text{bottles}}{\text{shift}}$

$\boxed{452}$ Sampling Spoons

Information not yet determined. Data will be in the Field Sampling Plan. Quantities are not expected to be significant.

V. WATER STREAMS

(Source: Eric Gosswiller)

501 Dust Suppression Water [Sheets 1 & 2]

To be verified by DSS vendor.

502 WES Fire Water [Sheets 1]

Volume, max = 60,000 gal

Rate = 30,000 gal/hr

503 PGS Fire Water [Sheets 1 & 3]

Volume, mas = 750 gal

Rate = 1,500 gal/hr

504 RCS Dry Pipe Fire Water [Sheets 1 & 2]

Volume, max = 36,000 gal

Rate = 18,000 gal/hr

505 RCS Manual Deluge Nozzels [Sheets 1 & 2]

Volume, max = 60,000 gal

Rate = 30,000 gal/hr

Appendix B
Conceptual Design Calculations

DESCRIPTION:

These calculations show the volumes, weights, and processing rates expected during the retrieval operations under the OU 7-10 Glovebox Excavator Method Project. The calculations in this appendix were prepared as part of the conceptual design, and have been superceded by calculations in the main body of this document.

GENERAL ASSUMPTIONS:

1. Depth of overburden is 3.5 ft.
   [Source: Process engineering assumption, Mark Borland, based on probe data in *OU 7-10 Stage 1 Subsurface Exploration and Treatability Studies Report (Draft)*, INEEL/EXT-2000-00403, 2000]
   $D_{OB} := 3.5 \cdot ft$

2. Depth of waste is 7.5 ft.
   [Source: Same as assumption #1.]
   $D_W := 7.5 \cdot ft$

3. Excavation Area is a fan shape with 145-degree angle and 20-ft radius.
   [Source: Civil Engineering Decision--Scott Jensen, 10/01]
   $\theta := 145 \cdot deg$
   $r_o := 20 \cdot ft$

4. Typical angle of repose during excavation of INEEL soil is 52 degrees.
   [Source: INEEL Materials Testing Laboratory, Craig Bean, 11/01]
   $\beta_1 := 52 \cdot deg$

5. Range of angle of repose to consider is 45 to 60 degrees.
   [Source: Process Engineering Decision, Mark Borland, 10/01]
   $\beta_2 := 45 \cdot deg$
   $\beta_3 := 60 \cdot deg$

6. Average density of unexcavated soil at RWMC is 100 lb/ft^3.
   [Source: INEEL Materials Testing Laboratory, Craig Bean, 11/01]
   $\rho := 100 \cdot \frac{lb}{ft^3}$

7. Average density of excavated INEEL soil is 75 lb/ft^3.
   [Source: INEEL Materials Testing Laboratory, Craig Bean, 11/01]
   $\rho_{exc} := 75 \cdot \frac{lb}{ft^3}$

I. OVERBURDEN CALCULATIONS

Assumptions:

1. Overburden will be packaged in sacks in 4 x 4 x 4-ft stands.
   [Source: Process Engineering Decision--Mark Borland 11/01]

2. Amount of soil in 4 x 4 x 4-ft sacks is limited to 5000 lb each to protect the box from overloading.
   [Source: Process Engineering Assumption--Stephanie Walsh, 11/01]

3. Sacks will be filled to an average of 8 in. from the top.
   [Source: Process Engineering Decision--Stephanie Walsh 11/01]

4. Overburden is shored to 3.5 ft deep.
   [Source: Civil Engineering Decision--Scott Jensen, 10/01]

5. Twenty days will be allowed for retrieving overburden (actual excavation operations only) $T_{ob} := 20 \cdot days$
   [Source: Process Engineering Assumption--Stephanie Walsh 11/01]

A. Volume of Overburden

$$A_{OB} := \left(\frac{\theta}{360 \cdot deg}\right) \cdot \pi \cdot r_o^2$$

$A_{OB} = 506 ft^2$ Overburden excavation area

$$V_{OB} := A_{OB} \cdot D_{OB}$$

$V_{OB} = 1772 ft^3$

$V_{OB} = 66 yd^3$ Undisturbed overburden soil volume

$$f_{se} := \frac{\rho}{\rho_{exc}}$$

$f_{se} = 1.333$ Soil expansion factor

$$V_{OB\_exc} := V_{OB} \cdot f_{se}$$

$V_{OB\_exc} = 2362 ft^3$

$V_{OB\_exc} = 87 yd^3$ Excavated overburden soil volume

B. Number of Overburden Sacks and Weight of Each Sack

$$V_{sack} := (4\cdot ft)\cdot(4\cdot ft)\cdot(3\cdot ft + 4\cdot in)$$

$$V_{sack} = 53.3\,ft^3$$

Volume of a 4 x 4 x 4-ft sack, filled to 8 in. from top

$$Sacks := \frac{V_{OB\_exc}}{V_{sack}}$$

$$Sacks = 44\,sacks$$

Number of 4 x 4 x 4-ft sacks

$$W_{sack} := V_{sack}\cdot \rho_{exc}$$

$$W_{sack} = 4000\,lb$$

Total weight of a sack < 5000 lb

Sack weight is acceptable.

C. Estimated Overburden Retrieval Rate

$$Rate\_OB\_sacks := \frac{Sacks}{\left(T_{ob}\right)\cdot\left(2\cdot\frac{shifts}{day}\right)}$$

$$Rate\_OB\_sacks = 1.1\,\frac{sack}{shift}$$

Estimated retrieval rate for sacks of overburden

$$Rate\_OB := \frac{V_{OB\_exc}}{\left(T_{ob}\right)\cdot\left(2\cdot\frac{shifts}{day}\right)}$$

$$Rate\_OB = 59.1\,\frac{ft^3}{shift}$$

Estimated retrieval rate for sacks of overburden

II. WASTE CALCULATIONS - UNDISTURBED RETRIEVAL ZONE

Assumptions:

1. The pit inventory for the 40 x 40-ft area of investigation is an accurate estimate of the types of materials to be excavated in this project. The amounts are assumed to scale proportionally with the volume to be excavated. The materials estimated to be located in the 40 x 40-ft area down to underburden include the following:

741 Sludge	$N_{741} := 3 \cdot \text{drums}$
742 Sludge	$N_{742} := 27 \cdot \text{drums}$
743 Sludge	$N_{743} := 379 \cdot \text{drums}$
744 Sludge	$N_{744} := 2 \cdot \text{drums}$
745 Sludge	$N_{745} := 42 \cdot \text{drums}$
Graphite	$N_g := 28 \cdot \text{drums}$
Combustible Debris	$N_{cd} := 260 \cdot \text{drums}$
Noncombustible Debris	$N_{nd} := 22 \cdot \text{drums}$
Empty Drums	$N_e := 544 \cdot \text{drums}$

[Source: Einerson and Thomas, 1999, *Pit 9 Estimated Inventory of Radiological and Nonradiological Constituents*, INEEL/EXT-99-00602]

2. The buried drums are randomly and uniformly distributed so that the number of each type of drum within the actual retrieval pit can be scaled from the inventory in Assumption 1 by the ratio of the volumes of the waste layers. [Source: Process Engineering Assumption, Danny Anderson, 11/01]

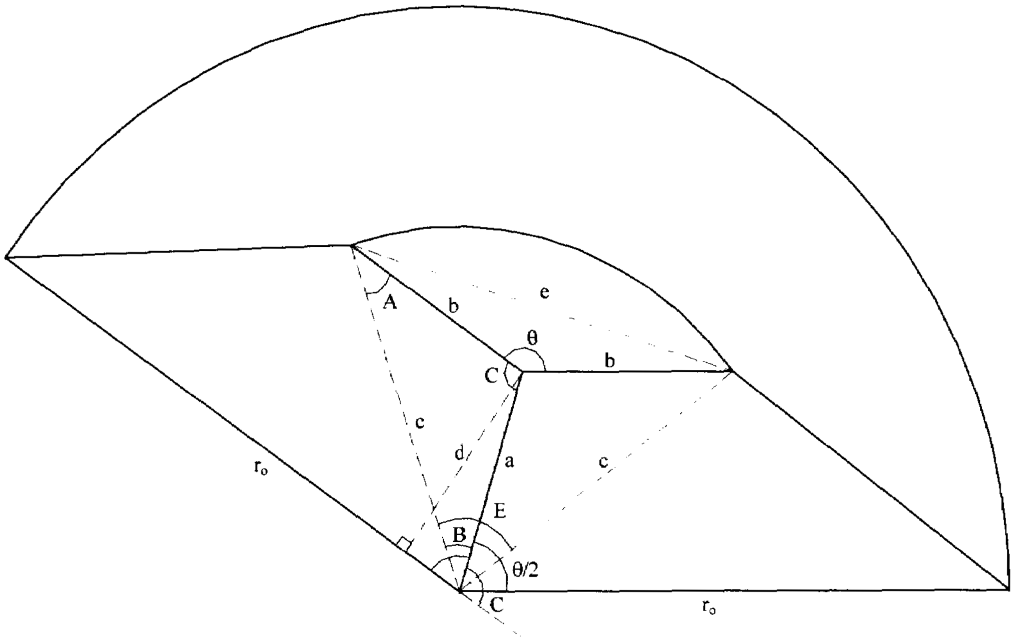
3. Packing factors for metals:

For noncombustible debris = 100% (not compactible)	$PF_{nd} := 1.0$	i.e., assume one 55-gal drum-worth of metal debris fills one 85-gal overpack
For decayed drum remnants = 20%.	$PF_{dr} := 0.2$	i.e., assume only 20% of a drum is still undecayed and intact, and five of these remnants fill one 85-gal overpack

[Source: Process Engineering Assumption, Mark Borland, 11/01]

A. Pit Volume in Waste Zone (Undisturbed)

Pit Shape



Dimension Definitions (as functions of angle of repose and pit depth)

$$a(\beta, D) := \frac{D}{\tan(\beta)\cdot\sin\left(\frac{\theta}{2}\right)} \qquad c(\beta, D) := r_o - \frac{D}{\tan(\beta)} \qquad E(\beta, D) := \theta - 2\cdot\operatorname{asin}\left(\frac{a(\beta, D)}{c(\beta, D)}\cdot\sin\left(\frac{\theta}{2}\right)\right)$$

Area of Fan Shape (at any depth and angle of repose)

$$A(\beta, D) := \frac{c(\beta, D)^2}{2}\cdot\left[(\sin(\theta))\cdot\left(\frac{1-\cos(E(\beta, D))}{1-\cos(\theta)}\right) + (E(\beta, D) - \sin(E(\beta, D)))\right]$$

Total Volume of Waste Zone (undisturbed)

$$V(\beta) := \int_0^{D_w} A(\beta, D)\, dD$$

$V(\beta_1) = 78.5\,yd^3$	$V(\beta_1) = 2121\,ft^3$	Volume of waste zone (52-degree angle of repose)
$V(\beta_2) = 65.6\,yd^3$	$V(\beta_2) = 1771\,ft^3$	Volume of waste zone (45-degree angle of repose)
$V(\beta_3) = 92.4\,yd^3$	$V(\beta_3) = 2496\,ft^3$	Volume of waste zone (60-degree angle of repose)

B. Drum Inventory in Retrieval Zone

Pit Size Scale Factor:
To estimate the amounts of different types of materials in the pit area to be excavated (the retrieval zone), a scale factor must be applied to the 40 x 40-ft² investigation area. This scale factor is a ratio of the volumes, and as such, will vary with the angle of repose during excavation.

$$V_{40x40} := (40 \cdot ft) \cdot (40 \cdot ft) \cdot D_w$$

$$V_{40x40} = 444.4\,yd^3$$

Volume of waste in 40 x 40-ft investigation pit.

$$V_{40x40} = 12000\,ft^3$$

$$sf(\beta) := \frac{V(\beta)}{V_{40x40}}$$

$sf(\beta_1) = 0.177$	Scale factor (52-degree angle of repose)
$sf(\beta_2) = 0.148$	Scale factor (45-degree angle of repose)
$sf(\beta_3) = 0.208$	Scale factor (60-degree angle of repose)

Scaled Waste Drum Inventory (anticipated drums in selected retrieval zone)

741 Sludge	$N_{741}(\beta) := \text{roundup}(N_{741} \cdot sf(\beta))$	$N_{741}(\beta_1) = 1$ drum $N_{741}(\beta_2) = 1$ drum $N_{741}(\beta_3) = 1$ drum
742 Sludge	$N_{742}(\beta) := \text{roundup}(N_{742} \cdot sf(\beta))$	$N_{742}(\beta_1) = 5$ drums $N_{742}(\beta_2) = 4$ drums $N_{742}(\beta_3) = 6$ drums
743 Sludge	$N_{743}(\beta) := \text{roundup}(N_{743} \cdot sf(\beta))$	$N_{743}(\beta_1) = 67$ drums $N_{743}(\beta_2) = 56$ drums $N_{743}(\beta_3) = 79$ drums
744 Sludge	$N_{744}(\beta) := \text{roundup}(N_{744} \cdot sf(\beta))$	$N_{744}(\beta_1) = 1$ drum $N_{744}(\beta_2) = 1$ drum $N_{744}(\beta_3) = 1$ drum
745 Sludge	$N_{745}(\beta) := \text{roundup}(N_{745} \cdot sf(\beta))$	$N_{745}(\beta_1) = 8$ drums $N_{745}(\beta_2) = 7$ drums $N_{745}(\beta_3) = 9$ drums
Graphite	$N_g(\beta) := \text{roundup}(N_g \cdot sf(\beta))$	$N_g(\beta_1) = 5$ drums $N_g(\beta_2) = 5$ drums $N_g(\beta_3) = 6$ drums
Comb. Debris	$N_{cd}(\beta) := \text{roundup}(N_{cd} \cdot sf(\beta))$	$N_{cd}(\beta_1) = 46$ drums $N_{cd}(\beta_2) = 39$ drums $N_{cd}(\beta_3) = 55$ drums
Noncomb. Debris	$N_{nd}(\beta) := \text{roundup}(N_{nd} \cdot sf(\beta))$	$N_{nd}(\beta_1) = 4$ drums $N_{nd}(\beta_2) = 4$ drums $N_{nd}(\beta_3) = 5$ drums
Empty Drums	$N_e(\beta) := \text{roundup}(N_e \cdot sf(\beta))$	$N_e(\beta_1) = 97$ drums $N_e(\beta_2) = 81$ drums $N_e(\beta_3) = 114$ drums

C. Waste and Interstitial Soil Volumes (undisturbed)

External volume of a 55-gal drum

$\phi_{od} := 24 \cdot in$

$H_{drum} := 32 \cdot in$

Outer diameter and height of 55-gal drum [Source: SPC-171, Stock Material Specification, UN1A2/X395/S and DOT 7A, Type A, 55-gal Combination Open Head Carbon Steel Drums with Plastic Liner]

$$V_e := H_{drum} \cdot \pi \cdot \left(\frac{\phi_{od}}{2}\right)^2$$

$V_e = 8.38 \frac{ft^3}{drum}$ External Volume of 55-gal drum

Total Number of Waste Drums in Retrieval Zone

$$N_T(\beta) := N_{741}(\beta) + N_{742}(\beta) + N_{743}(\beta) + N_{744}(\beta) + N_{745}(\beta) \ldots + N_g(\beta) + N_{cd}(\beta) + N_{nd}(\beta) + N_e(\beta)$$

$N_T(\beta_1) = 234\,drums$ Waste drums in retrieval zone (52-degree repose)

$N_T(\beta_2) = 198\,drums$ Waste drums in retrieval zone (45-degree repose)

$N_T(\beta_3) = 276\,drums$ Waste drums in retrieval zone (60-degree repose)

Volume of Waste Drums in Retrieval Zone (accounts for compression of empty drums)

$$V_w(\beta) := \left[\left(N_T(\beta) - N_e(\beta)\right) + N_e(\beta) \cdot PF_{dr}\right] \cdot V_e$$

$V_w(\beta_1) = 48.5\,yd^3$ Volume of drum waste (52-degree repose)

$V_w(\beta_2) = 41.3\,yd^3$ Volume of drum waste (45-degree repose)

$V_w(\beta_3) = 57.3\,yd^3$ Volume of drum waste (60-degree repose)

Volume of Interstitial Soil in Retrieval Zone

$$V_i(\beta) := V(\beta) - V_w(\beta)$$

$V_i(\beta_1) = 30\,yd^3$ Volume of interstitial soil (52-degree repose)

$V_i(\beta_2) = 24.3\,yd^3$ Volume of interstitial soil (45-degree repose)

$V_i(\beta_3) = 35.1\,yd^3$ Volume of interstitial soil (60-degree repose)

III. WASTE CALCULATIONS - REPACKAGED MATERIALS

Assumptions:

1. 25% of combustible debris drums contain an outlier object that will be bagged out of the glovebox, rather than packaged in a 55-gal drum. [Source: Process Engineering Assumption, Mark Borland, 11/01]

$k_{outlier} := 0.25$

2. Noncombustible debris (metals), emptied intact drums, and decayed drum remnanats are all packed in 85-gal overpack drums. [Source: Process Engineering Decision Mark Borland, 11/01]

3. The increase in volume of soil in the waste zone from excavation is approximately 20%. [Source: Process Engineering Assumption, Mark Borland, 11/01]

$f_{we} := 1.20$

4. Drums will be filled to 85% of capacity. [Source: Process Engineering Assumption, Mark Borland, 11/01, based on INEEL historical practice]

$f_d := 0.85$

A. Total Number of 55-gal Drums of Repackaged Waste Material

55-gal Drums - Repackaged Drum Waste

$$N_{sludge}(\beta) := \text{roundup}\left[\left(N_{741}(\beta) + N_{742}(\beta) + N_{743}(\beta) + N_{744}(\beta) + N_{745}(\beta)\right)\cdot\frac{f_{we}}{f_d}\right]$$

$N_{sludge}(\beta_1) = 116\,\text{drums}$ Number of sludge drums (52-degree repose)

$N_{sludge}(\beta_2) = 98\,\text{drums}$ Number of sludge drums (45-degree repose)

$N_{sludge}(\beta_3) = 136\,\text{drums}$ Number of sludge drums (60-degree repose)

$$N_{graphite}(\beta) := \text{roundup}\left(N_g(\beta)\cdot\frac{f_{we}}{f_d}\right)$$

$N_{graphite}(\beta_1) = 8\,\text{drums}$ Number of graphite drums (52-degree repose)

$N_{graphite}(\beta_2) = 8\,\text{drums}$ Number of graphite drums (45-degree repose)

$N_{graphite}(\beta_3) = 9\,\text{drums}$ Number of graphite drums (60-degree repose)

$$N_{cdebris}(\beta) := \text{roundup}\left(N_{cd}(\beta)\cdot\frac{f_{we}}{f_d}\right)$$

$N_{cdebris}(\beta_1) = 65\,\text{drums}$ Number of comb. debris drums (52-degree repose)

$N_{cdebris}(\beta_2) = 56\,\text{drums}$ Number of comb. debris drums (45-degree repose)

$N_{cdebris}(\beta_3) = 78\,\text{drums}$ Number of comb. debris drums (60-degree repose)

55-gal Drums - Repackaged Interstitial Soil

Number of 55-gal Drums Filled with Interstitial Soil

$\phi_i := 22 \cdot \text{in}$

$H := 31.75 \cdot \text{in}$

Inner diameter and height of 55-gal drum (Source: SPC-171, Stock Material Specification, UN1A2/X395/S and DOT 7A, Type A, 55-gal Combination Open Head Carbon Steel Drums with Plastic Liner)

$$V_d := H \cdot \pi \cdot \left(\frac{\phi_i}{2}\right)^2$$

$$V_d = 6.98 \frac{\text{ft}^3}{\text{drum}}$$

Internal Volume of 55-gal drum

$$N_{intsoil}(\beta) := \text{roundup}\left(\frac{V_i(\beta)}{V_d} \cdot \frac{f_{we}}{f_d}\right)$$

$N_{intsoil}(\beta_1) = 164 \text{drums}$ Repackaged interstitial soil drums (52-degree repose)

$N_{intsoil}(\beta_2) = 133 \text{drums}$ Repackaged interstitial soil drums (45-degree repose)

$N_{intsoil}(\beta_3) = 192 \text{drums}$ Repackaged interstitial soil drums (60-degree repose)

Bagged-Out Outlier Objects

Number of outlier objects to be bagged out (see Assumption II.3)

$$N_{outlier}(\beta) := \text{roundup}\left(N_{cd}(\beta) \cdot k_{outlier}\right)$$

$N_{outlier}(\beta_1) = 12 \text{outliers}$ Number of outlier objects (52-degree repose)

$N_{outlier}(\beta_2) = 10 \text{outliers}$ Number of outlier objects (45-degree repose)

$N_{outlier}(\beta_3) = 14 \text{outliers}$ Number of outlier objects (60-degree repose)

Total Number of 55-gal Drums of Repackaged Waste

Total Number of Packaged 55-gal Drums

$$N_{55}(\beta) := N_{sludge}(\beta) + N_{graphite}(\beta) + N_{cdebris}(\beta) + N_{intsoil}(\beta)$$

$N_{55}(\beta_1) = 353 \text{drums}$ 55-gal drums of repackaged waste (52-degree repose)

$N_{55}(\beta_2) = 295 \text{drums}$ 55-gal drums of repackaged waste (45-degree repose)

$N_{55}(\beta_3) = 415 \text{drums}$ 55-gal drums of repackaged waste (60-degree repose)

B. 85-gal Overpack Drums

Number of 85-gal Overpacks Filled with Noncombustible Debris (Metal) $N_{85.nd}(\beta) := N_{nd}(\beta) \cdot PF_{nd}$

Number of 85-gal Overpacks Filled with Compacted Decayed Drum Remnants $N_{85.dr}(\beta) := \text{roundup}\left(N_T(\beta) \cdot PF_{dr}\right)$

Total 85-gal Overpacks

$$N_{85}(\beta) := N_{85.nd}(\beta) + N_{85.dr}(\beta)$$

$N_{85}(\beta_1) = 51$ drums — 85-gal overpack drums of repackaged waste (52-degree repose)

$N_{85}(\beta_2) = 44$ drums — 85-gal overpack drums of repackaged waste (45-degree repose)

$N_{85}(\beta_3) = 61$ drums — 85-gal overpack drums of repackaged waste (60-degree repose)

C. Total Number of Drums of Repackaged Waste

$$N_{tot}(\beta) := N_{55}(\beta) + N_{85}(\beta)$$

$N_{tot}(\beta_1) = 404$ drums — Drums of repackaged waste (52-degree angle of repose)

$N_{tot}(\beta_2) = 339$ drums — Drums of repackaged waste (45-degree angle of repose)

$N_{tot}(\beta_3) = 476$ drums — Drums of repackaged waste (60-degree angle of repose)

D. Number of Waste Batches

Assumptions:

1. Batch size is an average 2.5 ft_3. A batch is the amount of material per scoop of the excavator.
[Source: Process Engineering Decision based on amount readily handled in glovebox tray, Mark Borland, 10/01]

$$\text{Batch}(\beta) := \frac{V(\beta)}{2.5 \cdot ft^3}$$

$\text{Batch}(\beta_1) = 848$ batches — Number of batches (52-degree angle of repose)

$\text{Batch}(\beta_2) = 708$ batches — Number of batches (45-degree angle of repose)

$\text{Batch}(\beta_3) = 998$ batches — Number of batches (60-degree angle of repose)

IV. PACKAGING RATE CALCULATIONS

A. Drum Output Rate

Assumptions:

1. 50 days will be allowed for retrieving and repackaging waste (actual operations only) $\quad T_{waste} := 50 \cdot \text{days}$
   [Source: Process engineering assumption, Stephanie Walsh, 11/01]

$$\text{Rate\_55}(\beta) := \frac{N_{55}(\beta)}{(T_{waste}) \cdot 2 \cdot \frac{\text{shifts}}{\text{day}}}$$

$\text{Rate\_55}(\beta_1) = 3.5 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 55-gal drums (52-degree angle)

$\text{Rate\_55}(\beta_2) = 3 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 55-gal drums (45-degree angle)

$\text{Rate\_55}(\beta_3) = 4.2 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 55-gal drums (60-degree angle)

$$\text{Rate\_85}(\beta) := \frac{N_{85}(\beta)}{(T_{waste}) \cdot 2 \cdot \frac{\text{shifts}}{\text{day}}}$$

$\text{Rate\_85}(\beta_1) = 0.5 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 85-gal drums (52-degree angle)

$\text{Rate\_85}(\beta_2) = 0.4 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 85-gal drums (45-degree angle)

$\text{Rate\_85}(\beta_3) = 0.6 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 85-gal drums (60-degree angle)

$$\text{Rate\_waste}(\beta) := \frac{N_{tot}(\beta)}{(T_{waste}) \cdot 2 \cdot \frac{\text{shifts}}{\text{day}}}$$

$\text{Rate\_waste}(\beta_1) = 4 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged waste (52-degree angle)

$\text{Rate\_waste}(\beta_2) = 3.4 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged waste (45-degree angle)

$\text{Rate\_waste}(\beta_3) = 4.8 \frac{\text{drums}}{\text{shift}}$ Output rate for repackaged waste (60-degree angle)

B. Volume Output Rate

$$\text{Rate\_vol}(\beta) := \frac{V(\beta)}{(T_{waste}) \cdot 2 \cdot \frac{\text{shifts}}{\text{day}}}$$

$$\text{Rate\_vol}(\beta_1) = 21.2 \frac{\text{ft}^3}{\text{shift}}$$ Output rate for repackaged waste (52-degree angle)

$$\text{Rate\_vol}(\beta_2) = 17.7 \frac{\text{ft}^3}{\text{shift}}$$ Output rate for repackaged waste (45-degree angle)

$$\text{Rate\_vol}(\beta_3) = 25 \frac{\text{ft}^3}{\text{shift}}$$ Output rate for repackaged waste (60-degree angle)

CONCEPTUAL DESIGN CALCULATION SUMMARY

I. Overburden

$V_{OB} = 66\,yd^3$	Undisturbed overburden soil volume
$V_{OB\_exc} = 87\,yd^3$	Excavated Overburden Soil Volume
$Sacks = 44\,sacks$	Number of 4 x 4 x 4-ft sacks
$W_{sack} = 4000\,lb$	Total weight of a sack < 5000 lb
$Rate\_OB\_sacks = 1.1\,\frac{sack}{shift}$	Required retrieval rate for sacks of overburden.

II. Waste -- Undisturbed Retrieval Zone

$V(\beta_1) = 78.5\,yd^3$	$V(\beta_1) = 2121\,ft^3$	Volume of waste zone (52-degree angle of repose)
$V(\beta_2) = 65.6\,yd^3$	$V(\beta_2) = 1771\,ft^3$	Volume of waste zone (45-degree angle of repose)
$V(\beta_3) = 92.4\,yd^3$	$V(\beta_3) = 2496\,ft^3$	Volume of waste zone (60-degree angle of repose)

III. Waste - Repackaged Materials

$N_{55}(\beta_1) = 353\,drums$	55-gallon drums of repackaged waste (52-degree repose)
$N_{55}(\beta_2) = 295\,drums$	55-gallon drums of repackaged waste (45-degree repose)
$N_{55}(\beta_3) = 415\,drums$	55-gallon drums of repackaged waste (60-degree repose)
$N_{85}(\beta_1) = 51\,drums$	85-gallon overpack drums of repackaged waste (52-degree repose)
$N_{85}(\beta_2) = 44\,drums$	85-gallon overpack drums of repackaged waste (45-degree repose)
$N_{85}(\beta_3) = 61\,drums$	85-gallon overpack drums of repackaged waste (60-degree repose)
$N_{tot}(\beta_1) = 404\,drums$	Drums of repackaged waste (52-degree angle of repose)
$N_{tot}(\beta_2) = 339\,drums$	Drums of repackaged waste (45-degree angle of repose)
$N_{tot}(\beta_3) = 476\,drums$	Drums of repackaged waste (60-degree angle of repose)
$Batch(\beta_1) = 848\,batches$	Number of batches (52-degree angle of repose)
$Batch(\beta_2) = 708\,batches$	Number of batches (45-degree angle of repose)
$Batch(\beta_3) = 998\,batches$	Number of batches (60-degree angle of repose)

$\text{Rate\_55}(\beta_1) = 3.5\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 55-gal drums (52-degree angle)

$\text{Rate\_55}(\beta_2) = 3\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 55-gal drums (45-degree angle)

$\text{Rate\_55}(\beta_3) = 4.2\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 55-gal drums (60-degree angle)

$\text{Rate\_85}(\beta_1) = 0.5\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 85-gal drums (52-degree angle)

$\text{Rate\_85}(\beta_2) = 0.4\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 85-gal drums (45-degree angle)

$\text{Rate\_85}(\beta_3) = 0.6\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged 85-gal drums (60-degree angle)

$\text{Rate\_waste}(\beta_1) = 4\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged waste (52-degree angle)

$\text{Rate\_waste}(\beta_2) = 3.4\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged waste (45-degree angle)

$\text{Rate\_waste}(\beta_3) = 4.8\,\frac{\text{drums}}{\text{shift}}$ Output rate for repackaged waste (60-degree angle)

$\text{Rate\_vol}(\beta_1) = 21.2\,\frac{\text{ft}^3}{\text{shift}}$ Output rate for repackaged waste (52-degree angle)

$\text{Rate\_vol}(\beta_2) = 17.7\,\frac{\text{ft}^3}{\text{shift}}$ Output rate for repackaged waste (45-degree angle)

$\text{Rate\_vol}(\beta_3) = 25\,\frac{\text{ft}^3}{\text{shift}}$ Output rate for repackaged waste (60-degree angle)